VORTEX GENERATION DUE TO COASTAL AND TOPOGRAPHIC INTERACTIONS

George F. Carnevale
Scripps Institution of Oceanography
University California San Diego
9500 Gilman Drive
La Jolla, CA 92093-0225
phone:(619) 534-4775 fax:(619) 534-987 email: gcarnevale@ucsd.edu
Award #: N00014-96-1-0065

LONG-TERM GOALS

The basic goal is to achieve a better understanding of turbulent flow in terms of the laws that govern the behavior of vortices and waves and their interactions. Our program of research investigates how vortices evolve and interact under oceanographically relevant forcings and the role of waves in their evolution. In order to understand and model ocean flows, we need insight into how vortices and waves are generated and propagate in diverse situations, how they interact with each other, and how they are affected by their environment. Ultimately, a theory of oceanic turbulent flow is necessarily statistical, but a proper statistical formulation requires an understanding of the nature of the elemental flow structures.

SCIENTIFIC OBJECTIVES

The objective of this project is to gain a better understanding of the interaction of vortices with coastlines in the presence of bottom topography and gradients of ambient vorticity (e.g. the beta-effect). The first part of the investigation focused on the evolution of vortices that approach a coastline from the open sea. The second part examines the generation of vortices and currents by the interaction of boundary currents with the coast and off-shore topography.

APPROACH

This investigation involves analytical studies, numerical simulations and laboratory experiments. We have used spectral, finite difference and point vortex (particle-in-cell) methods to simulate quasi-geostrophic and shallow-water dynamics near a coast. Transform methods and perturbation techniques have been used to provide analytic solutions in both quasi-geostrophic and shallow water theory. Laboratory experiments have been performed with a rotating tank to verify the theoretical and numerical predictions.

TASKS COMPLETED

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE **Vortex Generation Due to Coastal and Topographic Interactions**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of California, San Diego,Scripps Institution of Oceanography,La Jolla,CA,92093**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**3**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

We have performed a series of numerical simulations exploring the collision of a dipolar vortex with a coast. The primary focus of this investigation was to determine the relative importance of the beta-effect and viscous generation at the coast with regard to the possible rebound of vortices from the coast. The amount of coastal fluid transported away from the coast after the collision was monitored and plotted as a function of beta and the angle of incidence of the dipole at the coast. This numerical study was followed by a series of laboratory experiments in which dipoles were created in a rotating tank and allowed to collide with the wall of the tank. In these experiments the beta-effect was provided by a sloping bottom. A manuscript on this subject was prepared and submitted to the Journal of Fluid Mechanics; it has been accepted and in now in press (Carnevale, Fuentes and Orlandi 1997). For the problem of vortex generation by a boundary current over topography, we developed a finite-difference quasi-geostrophic code with radiation boundary conditions on the sides away form the coast. This code is being used in a series of simulations to determine the simplest conditions under which the presence of a step-like topography aligned perpendicular to the coast will cause generation of vortices in a coastal current and the generation of off-shore flow along the topography. As part of this project, we have solved analytically the steady-state quasi-geostrophic problem for an idealized escarpment or step that intersects the coastline perpendicularly. A manuscript on this topic was prepared and has been submitted to the Journal of Physical Oceanography. In addition to the analytical and numerical studies of coastal flow across an an escarpment, we have also performed a preliminary series of laboratory experiments in a rotating tank. These tend to confirm the numerical and analytical results. We intend to pursue the laboratory experiments to determine the limits of applicability of the numerical and analytical results and to help direct future numerical work.

RESULTS

Through numerical simulations and laboratory experiments, we have measured the dependence on beta of the point of separation of a vortex from the coast in the dipole rebound problem. A simple analytical model was proposed to explain this dependence. This model was used to provide a criterion for determining in which situations the beta-effect will dominate the viscous boundary-layer effect in vortex rebound. With regard to the amount of fluid which leaves the coastal region, we have made measurements as a function of beta and also the angle of incidence. The results show that, when the beta-effect dominates, the amount of fluid that is lost permanently from the coastal zone is approximately the same as the amount of fluid contained in the original dipole and is roughly independent of beta and the angle of incidence. For the problem of coastal flow over an escarpment, our theoretical result indicated that, for coastal boundary current of exponential profile, an offshore flow along the escarpment was possible only in the case in which the fluid depth decreases with the coast on the right (right-handed geometry). In the case with the coast on the left, no stationary off-shore flow was found. We have compared our analytic solution to results from numerical simulations. In these simulations, we start from a state of rest and slowly introduce a coastal current by an inflow boundary condition. In the case of the right-handed geometry, a stationary off-shore flow along the topography forms, and the long-term state corresponds closely to the analytical predictions. In the case of the left-handed geometry, no steady state was reached, and there continues to be fluctuations and some eddy generation in the flow over the topography. To a certain extent this difference between the flows in the left and right handed geometries is explained by the direction of propagation of long topographic Rossby waves. Only in the right-handed geometry will these waves carry information away from the coast and, hence, establish a steady current along the topography,.

IMPACT/APPLICATIONS

The results on vortex collisions with a coast may be useful in understanding the relative roles of the beta-effect, viscous boundary layer effects, and topography in determining the trajectories and evolution of vortices near coasts. Since the relationships between these effects vary with latitude, our results may help explain, in part, the variation of the character of the turbulent boundary current as a function of latitude. Our results on coastal current bifurcations due to topography may be useful in analyzing the flow in the Adriatic, the Bering sea, or other places where strong topographic variations occur in the along-shore direction. We also believe these studies help explain some unexpected results previously found in laboratory experiments on coastal flow over a step.

TRANSITIONS

Our results on coastal flow over a step drew interest from the experimental group at Eindhoven, the Netherlands. Under professor G-J van Heijst, a Ph.D. project on this and related coastal problems has been started.

RELATED PROJECTS

Professor Longhetto of the University of Torino has submitted a proposal to perform large-scale versions of the coastal current bifurcation problem in the large rotating tank in Grenoble.

REFERENCES

Carnevale G.F., Fuentes, O.V. and Orlandi, P., 1997, Inviscid dipole-vortex rebound from a wall or coast (J. Fluid Mech., in press).

Carnevale, G.F., Llewellyn Smith, S.G., Crisciani, F., Purini, R. and Serravall, R. 1997 Bifurcation of a coastal current at an escarpment. (submitted to J. Physical Oceanography)